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Morphologies of the Nebulae around "born-again" Central Stars of Planetary Nebulae

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Abstract. While in the past spherodicity was assumed, and still is used in modeling of most nebulae, we know now that only a small number of planetary nebulae (PNe) are really spherical or at least nearly round. Round planetary nebulae are the minority of objects. In the case of those objects that underwent a very late helium flash (called VLTP objects or "born-again" PNe) it seems to be different. The first, hydrogen-rich PN, is more or less round. The ejecta from the VLTP event, in contrast, are extremely asymmetrical.

1. The VLTP nebulae

The known family of VLTP objects is rather small. Only a few show a clear signature of a VLTP event (first described by Schönberner 1979): a hydrogen rich normal PN and prominent hydrogen poor ejecta near the core - and if observable - a hydrogen poor central star (CSPN). Prominent members from the review by Zijlstra (2002) are presented here to point out their common morphologies. Below, we show a possible way to search for similar objects by means of their global properties.

1.1. A30 & A78: the Seniors

A30 (GPN G208.55+33.28) is –probably– the oldest, and best studied member of the family. Jacoby & Ford (1983) discovered the unusual abundance of the central knots. A30 shows all features of a "born-again" PN (see Fig. 1) and can be considered as the prototype of this class:

- A hydrogen poor central star with prominent C and O wind emission lines and unusual wind properties (Yadoumaru & Tamura 1994).

- Fast moving hydrogen-poor knots embedded in a normal old PN (Jacoby & Ford 1983).
- Unusual hot and small carbonous dust grains near the core in a ring/belt-like structure (Borkowski et al. 1994).

The old nebula is a perfect –and rare–example of a round PN. The hydrogen-poor and dusty ejecta are, in contrast, strongly bipolar(Fig. 1, inserts)

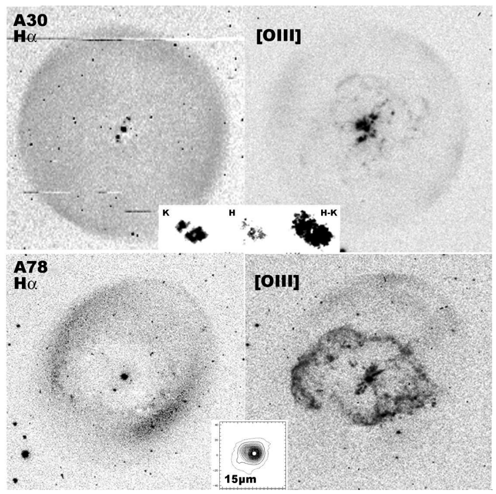

Figure 1. Abell 30 (top) and Abell 78 (bottom): The Hα image (A30 by Balick (1987), A78 from Calar Alto) and the [OIII] images (ING archive and Calar Alto) show the perfectly round shape of the hydrogen-rich old PN and the clumpy ejecta. The inserts show infrared data: K & H from Kimeswenger et al. (1997), ISO 15μm from Kimeswenger et al. (1998). They indicate a belt of hot dusty material perpendicular to the main axis as defined by the VLTP ejecta in [OIII].

The old nebula of A78 (GPN G081.29-14.91) also shows considerable symmetry. It appears more barrel-shaped, inclined to the line of sight. But this view is overemphasized by an excitation effect. [OIII] is more prominent at the poles. In contrast to the symmetry of the outer nebula, Kimeswenger et al. (1998) show in their ISO study a belt of dusty material perpendicular to the main direction of the fast ejecta. In this case the clumpy ring extends into the area of the old PN. Thus, in both cases the old nebula is far more spherical than the newly ejected VLTP material.

1.2. V605 Aql & V4334 Sgr: Bipolarity at young ages

V4334 Sgr (Sakurai's object; the CSPN of GPN G010.47+04.41) and V605 Aql (the CSPN of A58 = GPN G037.60−05.16) underwent VLTP events within the past century. Their outer nebulae show a large degree of spherical symmetry, for A58 affected by ISM interaction (Wareing et al. 2007). The inner cores show spectroscopic evidence for bipolarity, as shown in more detail in Kimeswenger et al. (2007). The core of A58 also shows position offsets of the central emission at different wavelengths (Fig. 2), indicative of an extinction torus. For V605 Aql such a bipolarity of the dust distribution already has been suspected earlier by Pollacco et al. (1992) and Koller & Kimeswenger (2001).

The asymmetric shell of V4334 Sgr became visible during the second and third year after the return to the cold luminous state: it was monitored in detail by Kimeswenger & Koller (2002).

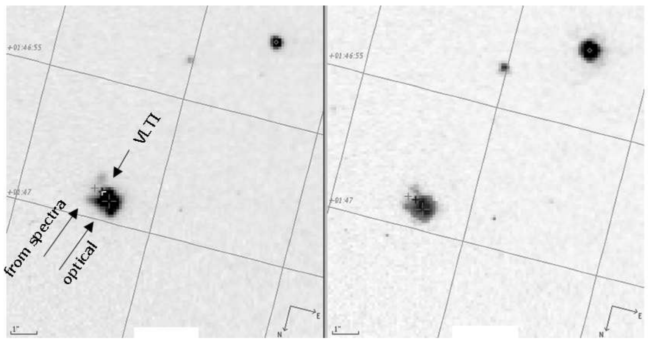

Figure 2. The HST [NII] and [OIII] images of A58 with a re-calibrated coordinate system. The center derived by spectra in Kimeswenger et al. (2007) and by one of us (MH) using VLA data is clearly offset to the optical center of the knots.

2. Discussion

The strong bipolarity of the VLTP events requires a common explanation. A binary-induced shaping, or stellar rotation, is less likely, first because of the nature of the VLTP event, and second because of the absence of strong shaping in the old ejecta. The bipolarity can be amplified during the transition from the carbon-rich post-AGB like state to the early hot core when a fast hot wind crashes into the high extinction VLTP ejecta (see e.g. Icke 2007). This requires an initial asymmetry during the VLTP flash. Fully convective configurations are dominated by a dipole convective flow structure (Kuhlen et al. 2006; Porter & Woodward 2000). One may speculate that the expanding VLTP convection may equally be dominated by a dipolar flow, since the convectively stable core in the middle will eventually occupy only a small fraction of the expanding star.

The family of old VLTP members is probably incomplete. Górny & Tylenda (2000) list 65 hydrogen poor central stars of PNe. Hot PG1159 white dwarfs are also thought to be remnants of this kind of event. Less than half of them have a PN, but most of those having a PN do currently not show (prominent) hydrogen poor ejecta.

Beside detailed morphological analysis, we propose the use of the average nebular surface brightness $S_{\mathrm{H}\beta}$ vs. the surface brightness calculated from the stellar flux over the apparent size of the nebula S_{V} (see Górny & Tylenda 2000), to locate more "born-again" nebulae (Fig. 3). For V605 Aql/A58 the flux of the current CSPN was calculated from predicted values of Herwig (2001). For objects lacking an H_β flux we estimated it from the radio flux. While the old nebula dominating the vertical axis of this graph passes through its undisturbed evolution, the CSPN undergoes a rapid evolution. Thus the VLTP objects can be found far from the regular PNe (see Górny & Tylenda 2000, for the whole sample of normal PNe in this kind of graph).

The known “born-again” nebulae occupy a region below the track given by the original authors based on the track by Iben et al. (1983). They are well separated from those PNe having a PG1159 core without having hydrogen-poor dusty ejecta in the nebula. Thus may we have to think about two different branches of evolution – with and without a dusty phase ?

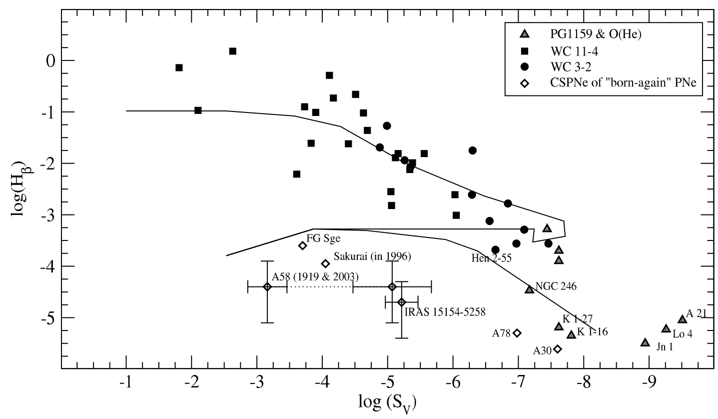

Figure 3. The diagram of the nebular surface brightness $S_{\mathrm{H}\beta}$ (corresponding to the evolution of the old nebula) vs. the surface brightness calculated from the CSPN flux S_{V} (corresponding to the evolution of the CSPN). For a detailed description of the graph see Górny & Tylenda (2000).

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